Planning and Operating Pecan Orchards With Drip and Microspray Irrigation Systems

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Drip irrigation allows precise application of water to plant roots. Small amounts of water are applied frequently to replace water withdrawn by the plant or lost by evaporation or deep seepage. Soil moisture in the area around the plant is thus maintained at a uniform level throughout the growing period. This increases growth and production potential because plants are not subjected to wet and dry cycles that normally occur with other irrigation methods.

Drip irrigation simplifies irrigation procedures, minimizes distribution and evaporation losses, and may reduce labor requirements. Less of the total soil area is wet with drip than with sprinkler and furrow systems, significantly reducing water required for irrigation and simplifying weed control. The irrigation system can be controlled automatically with a time clock and/or soil moisture sensors and automatic valves, thereby maintaining optimal soil moisture with minimum labor. Drip irrigation is used more often for orchard crops than for field crops, primarily because the spacing between emitters and laterals is greater, and system costs per acre are lower.

DRIP IRRIGATION SYSTEM LAYOUT

Water is distributed to individual trees through a pipeline system that should be planned carefully for the specific site, orchard size and shape, land slope, tree spacing, and water requirements. The system should provide reasonably uniform pressure at all emitters, require minimum material, and achieve maximum operating convenience.

Components of a typical drip irrigation system are illustrated in fig. 1. The *pipeline* is composed of a main line that carries water to manifolds and laterals.
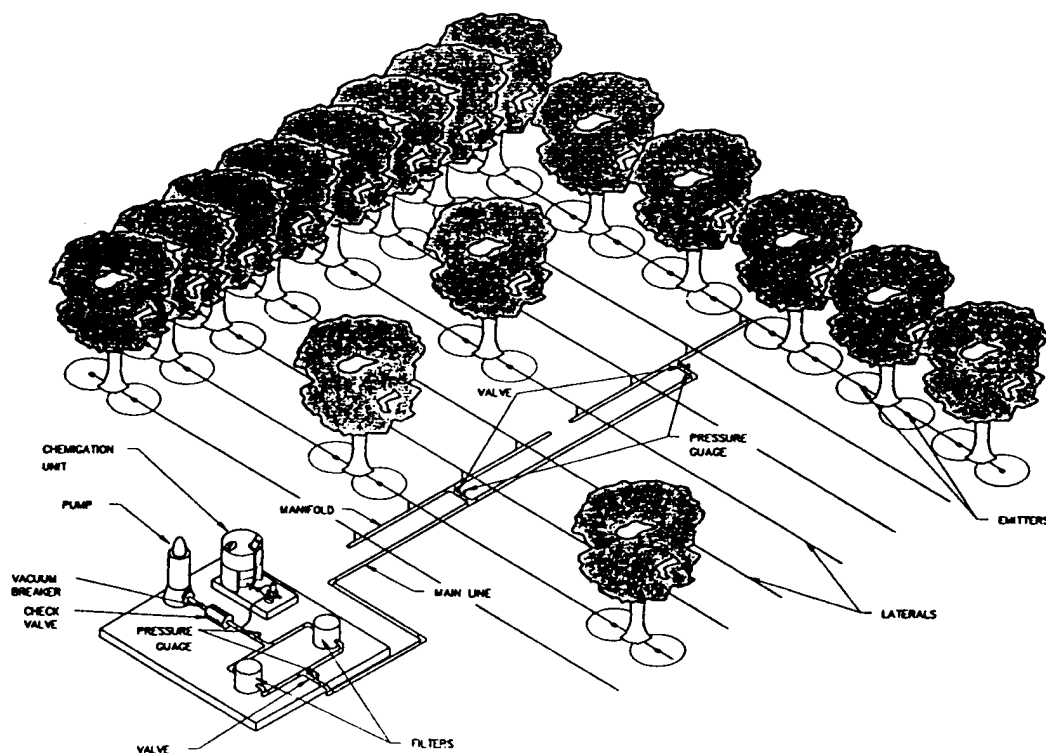

Fig. 1. Components of a typical orchard drip system.

Water flow is regulated using *manual* or *automatic valves*. *Pressure gauges* are located at critical points and are used to ensure proper system operating pressure. A *filter system* is installed in the main line to filter all water. Injecting fertilizers and other chemicals into the irrigation water often causes minerals to precipitate; thus, the *fertilizer injector equipment* should be installed upstream from the filter to filter precipitates. An *anti-siphon unit* consisting of a *check valve* and a *vacuum breaker* is installed in the main line between the pump and fertilizer injector to prevent flow of fertilizers or other chemicals back into the water source in the event that the irrigation pump stops during injection. Specific chemigation equipment is also required by federal regulations.

A lateral pipeline containing emitters is placed along each row of trees. In larger systems, the orchard may be divided into sections or blocks, with the laterals for each block connected to a separate manifold pipeline. The main line is normally connected at the center of the manifold (fig. 1). However, topography may dictate placing the connection at some other point. An *automatic pressure-regulating valve* or a *manual globe-type valve* with a pressure gauge is installed on the manifold side of the valve to allow for appropriate control of pressure in all blocks. Valves can be used to equalize pressure variations caused by elevation differences and friction losses, and to maintain sufficient minimum pressure throughout the system.

On moderate to steep slopes, laterals and tree rows generally should be across (or perpendicular to) the slope to help maintain more uniform pressure at the emitters. For slight, uniform slopes, proper water pressure in the laterals can sometimes be achieved by placing laterals along the direction of the slope to offset pressure loss caused by friction. Laterals that direct water flow up the slope should generally be avoided, especially when low-pressure emitters are used.

Water is released by emitters attached to the laterals near each tree. Application rates of emitters vary from 1/2–2 gallons per hour (GPH), while microsprinklers may discharge up to 10 GPH or sometimes more. Do not select an emitter that applies water faster than it can be absorbed by the soil. Most emitters can be installed underground. However, it is easier to adjust emitter location and to observe and clean clogged emitters when they are on the soil surface.

The size of main lines and manifolds should be selected carefully based on the water flow rate and pipeline length. As a general rule, pipe sizes are selected so that velocity of flow is less than 5 ft/sec to prevent excessive pressure loss and water hammer (table 1). Polyvinyl chloride (PVC) pipe is generally used for the main and manifold pipelines.

Table 1. Recommended maximum lateral lengths[1] for 1/2" plastic pipe with emitters for various flow rates in gallons per minute (GPM).

1/2" laterals with emitters	
GPM	Length (ft)
1.5	650
2.0	500
2.5	300
3.0	225

[1]Use manufacturer's recommendations when available.

Main and manifold pipelines are frequently installed underground with laterals on the surface, although laterals also may be underground. Underground pipelines last longer and do not interfere with field operations. Main and manifold pipelines are often set 18–24" below the surface, but site conditions may require other depths. Underground laterals are usually 12–15" below the surface, or below plow depth. Connection joints in underground pipelines should be checked for leaks before covering pipes with soil. The ditch may be partially backfilled as installation progresses, leaving only the connection joints exposed. It is best to cover underground pipelines when temperature is coolest, e.g., early morning.

Filters

Clean water is essential for successful drip irrigation, as sand, silt, organic material, and other foreign material can easily clog small emitter openings. Select a filtration system according to the types and quantity of foreign material in the water and the emitter characteristics, as recommended by the manufacturer. A filter system in the main pipeline near the pump is more economical and much easier to maintain than several filters located throughout the irrigation system.

Filters with corrosion-resistant stainless steel or bronze screens are available. These are usually adequate when the irrigation water contains only small amounts of sand. Two or more filters can be connected in short, parallel manifold pipelines to increase filtering capacity. Backflushing capability can be provided with an appropriate valve arrangement. Be sure the mesh size of the filtering screen is appropriate for the emitter chosen.

Filters with multi-stage screens may be required when water contains moderate to large amounts of sand. If sand is an extreme problem, settling tanks or sand separators can be installed upstream from the fil-

ter to remove a large amount of sand and reduce the filter load. Dual or oversized filters also will handle extra-heavy filter loads, but sand separators or settling tanks may be more economical.

Surface water such as rivers, canals, and ponds frequently requires more filtration than water from wells. It may be necessary to have both a synthetic fiber or metal screen intake filter *and* a fine-mesh screen or sand filters on the discharge side of the pump. Settling basins may be needed if the water contains considerable algae. Sand (or media) filters are commonly used for surface water sources. These filters are expensive, but are very effective and can be equipped for automatic flushing.

Equip filters with cleanout or flush valves so trapped particles can be removed easily. Daily flushing is necessary when water contains moderate amounts of sand or other material. Screens will need periodic, thorough cleaning. Pressure gauges installed on both sides of the filter provide an indication of filter clogging. A moderate to high pressure difference indicates the filter needs flushing or cleaning.

Lateral Pipelines

Lateral pipelines are usually flexible polyethylene or polybutylene pipe. Pipe sizes may be given by manufacturers in English or metric units (Note: 1" = 25.4 mm). Available sizes include 10 mm, 13 mm, 15 mm, 16 mm, and 3/8–1". Sizes most frequently used for lateral pipelines are 15 mm, 16 mm, and 1/2". Smaller sizes may be used for very short laterals and larger sizes for extra long laterals.

Select a good quality polyethylene or polybutylene (or other plastic formulation) tubing manufactured specifically for drip irrigation systems. Be sure pipe, fittings, and emitters are compatible. During installation, heat the end of the pipe in hot water if connections are extremely difficult.

The number of laterals required for each row of trees is determined primarily by tree size or spacing and emitter arrangement at the tree. For large trees such as pecans, one lateral for each row is normal when micro-sprinklers or tree loops are used. In-line or attached emitters are often used for smaller trees (peaches, apples, citrus). Two laterals of in-line emitters may be best for each row of mature pecan trees.

Underground lateral pipelines last longer and do not interfere with cultural and harvesting operations. Place underground laterals approximately 12" deep or below plow and freeze depths. Position single lateral pipelines with in-line emitters 2 ft from the tree trunk. Where two emitter pipelines are used, locate each pipeline one-fourth of the row spacing on each side of

the tree. Use emitter tubing to apply water within 12" of small trees.

Laterals placed on the surface should be "snaked" or left slightly loose along tree rows. In addition, leave 5–10 ft of extra pipe at each end so lateral and emitter locations can be adjusted easily. Extra lateral length is especially helpful when emitters are installed in-line. Flexible pipe also tends to "crawl" as it expands and contracts with temperature changes. Permissible lateral length is influenced by the diameter of the lateral, tree spacing, quantity of water delivered to each tree, type of emitter, and land slope. Design lateral lines that do not exceed the length, pressure loss, and flow rates recommended by the manufacturer.

With properly designed drip systems, there will be reasonably uniform water application by every emitter in the system. Many emitters are "pressure compensating," which means that their discharge rate varies little over a wide range of operating pressures. Other emitters discharge more water as pressure increases and less water as pressure decreases (fig. 2). Due to the difficulty of achieving absolutely uniform pressure throughout the system, most drip systems are designed for 90% uniformity. This means that the emitter with the lowest discharge rate will apply at least 90% as much water as the emitter with the highest discharge rate. Allowable pressure variation within the system or within a block in a large system can be determined with the pressure-discharge curve for the particular emitter selected. If a pressure-discharge curve is not available, an allowable pressure variation of no more than 20% is suggested as the design criterion.

Friction pressure loss in laterals can be determined using friction loss charts for the specific type of plastic pipe used. These charts are usually available from pipe manufacturers. Lateral diameter, length, and flow rate are needed to determine the pressure loss caused by friction. Friction pressure loss in a lateral (or any pipeline containing at least 10 uniformly sized and spaced emitters along its length) is about 40% of a pipe with no emitters (sometimes referred to as the 40% rule). Multiply pressure loss calculated from friction charts by 0.40 to determine pressure loss in the proposed laterals; then compare the calculated pressure loss with the allowable pressure variation. If the calculated pressure loss is greater than the allowable variation, decrease lateral length or increase lateral pipeline diameter. Head in feet (such as elevation differences) can be converted to psi (pounds per square inch) by dividing by 2.31 (2.31 feet of water = 1 psi). Guidelines for lateral length and flow rate in 1/2" lines with emitters are given in table 1.

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Manifold Pipelines

In larger orchards, water may be supplied to a "block" of several laterals through a pipeline called a manifold. The manifold is usually connected to the main line at the midpoint of the manifold in order to provide more uniform pressure to all laterals in the system. The manifold can be either polyethylene or PVC pipe and is usually installed underground.

Plan manifold pipelines to provide as nearly equal pressure at each lateral as possible. A globe valve or an automatic pressure regulating valve is installed between the main line and manifold to allow for pressure adjustment so all laterals have approximately equal pressure. Install a pressure gauge immediately downstream from the globe valve to measure at the midpoint of the manifold. Set the appropriate operating pressure by adjusting the globe valve. Maximum pressure loss in the manifold plus loss in the lateral should generally be less than 20% the emitter operating pressure. Select manifold pipe size on the basis of water flow rate and the corresponding friction pressure loss. Recommended maximum flow rates for some pipe sizes are listed in table 2. The 40% friction loss rule (see above) applies to manifold as well as lateral pipelines.

Table 2. **Approximate maximum flow rate (gallons per minute) in plastic pipe for drip irrigation.**

Manifold and pipeline sizes and flow rates	
Size (in.)	GPM
1	10
1 1/4	20
1 1/2	30
2	50

Emitters

The term "emitter" is often used to refer to any drip irrigation water discharge orifice. Various types, including in-line and barbed types, are available. With non-pressure-compensating emitters, an increase in pressure increases the emitter discharge rate, while a decrease in pressure decreases the discharge rate (fig. 2). A pressure-compensating emitter will discharge approximately the same amount of water under a wide range of pressures. Emitter manufacturers provide information on the relationship between pressure and water discharge for their emitters.

Emitters are sometimes classified according to their design operating pressure—low or high. Low-pressure emitters usually apply 1–2 GPH at operating pressures of 2–8 psi; high-pressure emitters typically apply 1 GPH at about 15 psi. The pressure-discharge curves in fig. 3 show that low-pressure emitters apply more water at a given pressure than high-pressure emitters. Do not use both high- and low-pressure emitters in the same drip irrigation system unless pressure-regulating devices are installed upstream from the low-pressure emitters. Do not use high- and low-pressure emitters in the same lateral pipeline.
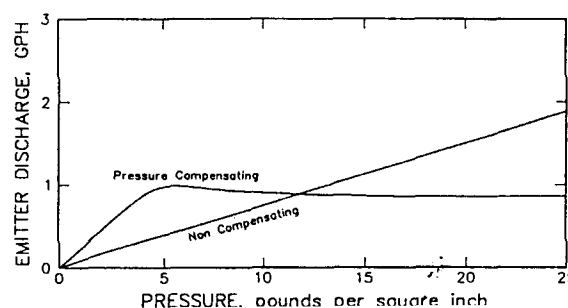

Fig. 2. **Typical relationship between emitter discharge and pressure for pressure-compensating and non-compensating emitters.**
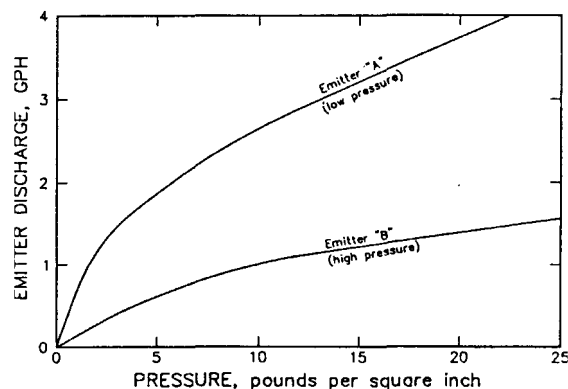

Fig. 3. **Pressure discharge relationship for low-pressure emitter and high-pressure emitter.**

The water discharge rate of high-pressure emitters is affected less by changes in land elevation within the orchard or friction pressure loss in the pipe than of low-pressure emitters. Laterals with low-pressure emitters cannot be as long as laterals with high-pressure emitters. All of these factors should be considered in selecting emitters and planning drip systems.

The number of emitters needed for each tree is influenced by water movement in the soil as well as the amount of water required by the tree. A soil that allows limited horizontal movement of water requires more emitters with lower discharge rates than a soil that will allow greater lateral spreading. The wetting pattern generally should cover at least 60% of the horizontal extent of the tree canopy and root zone. Diameter of the wetting pattern is affected by soil type, discharge rate, and the duration of each irrigation

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period.

The emitter arrangement at each tree should be considered carefully to provide convenient orchard care, easy emitter maintenance, and adequate irrigation. Typical emitter arrangements are shown in fig. 4. Emitters should be within 1–1.5 ft of the trunk of young, newly transplanted trees, but should be moved away from the trunk as trees grow. Water quality is a factor in emitter location because salts tend to concentrate at the edges of the wet soil area (fig. 5). It may be necessary to locate emitters so wet areas overlap at the tree trunk to prevent harmful accumulations of salt at or near the trunk.

Tree loops are often used for large trees such as pecans (fig. 4a). The loop is connected to the underground lateral pipeline and circles the tree between the trunk and the canopy line. Tree loops are usually 1/2" or 3/8" polyethylene pipe, 6–10 ft long initially, and contain one or two emitters. Additional sections of pipe 8–12 ft long, containing one emitter, are connected to the initial loop as the tree grows and requires more water. Large pecan trees typically require tree loops with 6–10 or more emitters.

In-line emitter arrangements (fig. 4b) have been used satisfactorily for smaller trees such as citrus, peaches, and apples. Two to four emitters are installed in the lateral so that wet areas slightly overlap in a line along the tree row. When laterals become too long to allow for the addition of emitters without ex-

cessive friction pressure loss, a dual-lateral arrangement (fig. 4c) may be used to supply additional water as the trees grow.

Measure emitter water discharge rates periodically using a graduated cylinder or other marked container. Graduated cylinders are frequently marked to measure volume in milliliters; use table 3 to convert milliliters per minute to gallons per hour. Emitter discharge rate should be checked at several locations over the orchard to ensure adequate and uniform irrigation. Also check operating pressure at the ends of lateral lines at different locations. Make pressure checks immediately if emitter discharge rates are less than planned.

Table 3. Conversion of milliliters per minute (ml/min) to gallons per hour (GPH).

(milliliters/minute x.015852 = gallons per hour)			
ml/min.	GPH	ml/min	GPH
35	.55	70	1.11
40	.63	75	1.19
45	.71	80	1.27
50	.79	85	1.35
55	.87	90	1.43
60	.95	95	1.51
65	1.03	100	1.59

a) tree loop
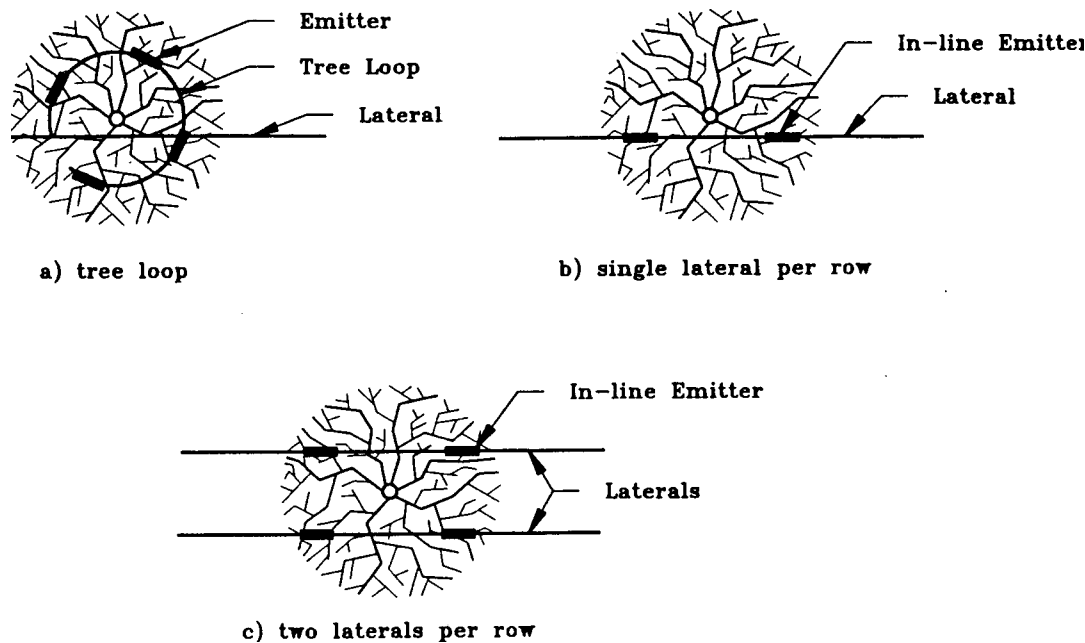
b) single lateral per row

c) two laterals per row

Fig. 4. Typical emitter arrangements: (a) emitters installed in a tree loop;(b) single lateral with in-line emitters; and (c) double lateral with in-line emitters.

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MICRO-SPRINKLERS AND MICRO-SPRAYERS

Micro-sprinklers (with moving parts) and micro-sprayers (without moving parts) are sometimes preferred over drip emitters. With these devices, water is discharged into the air and travels some distance before contacting the soil surface. Micro-sprinklers and micro-sprayers usually have higher flow rates than drip emitters, and wet larger soil surface areas with their circular or fan-shaped application patterns.

Fig. 5 illustrates typical soil moisture distribution under a micro-sprinkler or sprayer compared to a drip emitter. With drip emitters, small areas of nearly saturated soil may occur near the emitter as shown. Micro-sprinklers and sprayers spread water over a larger surface area and soil saturation is less likely to occur. Spreading water over larger soil surface areas is particularly advantageous on coarse, sandy soils (where water from a drip emitter moves very little laterally) and on fine-textured clay soils (where water from a drip emitter may puddle on the surface).

Micro-sprinklers and sprayers are available in a variety of application patterns from a full circle to fan-shaped or part-circle. Some of the application patterns available are shown in fig. 6. Some micro-sprinklers and sprayers have interchangeable nozzles so the spray pattern and discharge rate can be changed. Thus, a pattern that concentrates water near the tree can be used when the tree is small, but as the tree grows and the root system expands, the application pattern can be changed to wet a larger soil surface area.

Water droplets traveling through the air from a micro-sprayer or sprinkler are subject to evaporation loss. In addition, greater evaporation loss from the soil surface will occur because these methods wet larger surface area. Evaporation losses of 5–15% can be expected, depending upon temperature, wind, humidity, system pressure, and orifice size. Because a larger surface area is wet with micro-sprinklers and sprayers, increased weed germination and growth can be expected.

The *rate* of water flow to each tree will generally be four to ten times greater from micro-sprinklers or sprayers than from a drip system. Therefore, larger pipe sizes (except the main supply pipeline) will generally be required to obtain uniform water application over the orchard. Also, it may be necessary to divide the orchard into more blocks to route the water supply in sequence from block to block. Conversion of an existing drip system to a micro-sprayer or sprinkler system may result in unsatisfactory irrigation uniformity unless flow rate requirements and piping system hydraulics are evaluated adequately.

Because salts typically accumulate around the edges of the wet pattern (fig. 5), micro-sprinklers and sprayers may provide better control of soil salinity. However, drip emitters may be the better choice if the total salt content of the water is high, as the soil is maintained at a higher moisture content near the emitter.
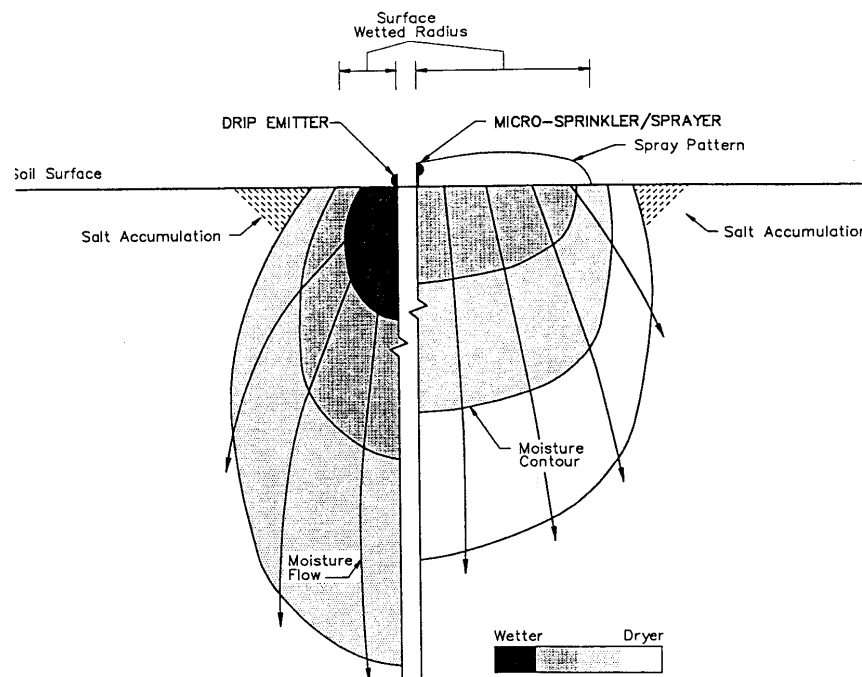

Fig. 5. Typical wetting patterns of drip emitters and micro-sprinklers.

IRRIGATION SYSTEM CAPACITY

Emitter selection and sizes of laterals and mainlines are based on a chosen or available system water capacity, usually expressed as GPM (gallons per minute). The irrigation system capacity must be large enough to provide the water required when the orchard is mature. For planning purposes, water requirements of orchards can be estimated from National Weather Service Class A evaporation pan rates or potential evapotranspiration (PET) rates based on Penman's equation, which uses climate data. Potential evapotranspiration is the amount of water used by grass that is well watered and fertilized. Pan evaporation and PET are influenced by environmental factors such as temperature, relative humidity, and wind. Each of these factors also influences the amount of water that trees require.

Pan evaporation and PET rates are related to tree water usage by a water use factor (WUF) expressed as a percentage. A WUF of 0.7 for pan evaporation has been used successfully for years in planning pecan orchard irrigation system capacity. Accordingly, WUF for PET in pecan orchards is 0.85.

The other factor used to estimate water requirements is area covered by plant canopy. In orchards the canopy area is based on the diameter of the circle formed by the tree drip line. The maximum potential size of the tree when mature should be used to calculate canopy diameter for determining irrigation system capacity and in sizing all irrigation pipelines. The canopy diameter of mature trees can be assumed to be equal to the tree spacing in the row. For example, the canopy of mature peach trees will be 18 ft in diameter when planted on a spacing of 18 ft X 24 ft. Pecan trees planted on a 35 ft X35 ft spacing will have a canopy diameter of 35 ft when mature.

Average potential evapotranspiration rates at various locations in New Mexico are given in table 4. These rates are the daily averages for each month of the year. Select the daily PET rate at the nearest location or average the rates shown for two or three stations nearest the orchard location. Normally, the maximum daily evaporation for the year occurs in June, July, or August; use the maximum value to plan irrigation system water capacity. The value selected from table 4 is the "E" value used in equations 1 and 3.

The daily maximum water requirement for each tree can be projected using the formula:

Equation 1

$$Q = A \ x \ E \ x \ WUF \ x \ 0.623$$

Where:

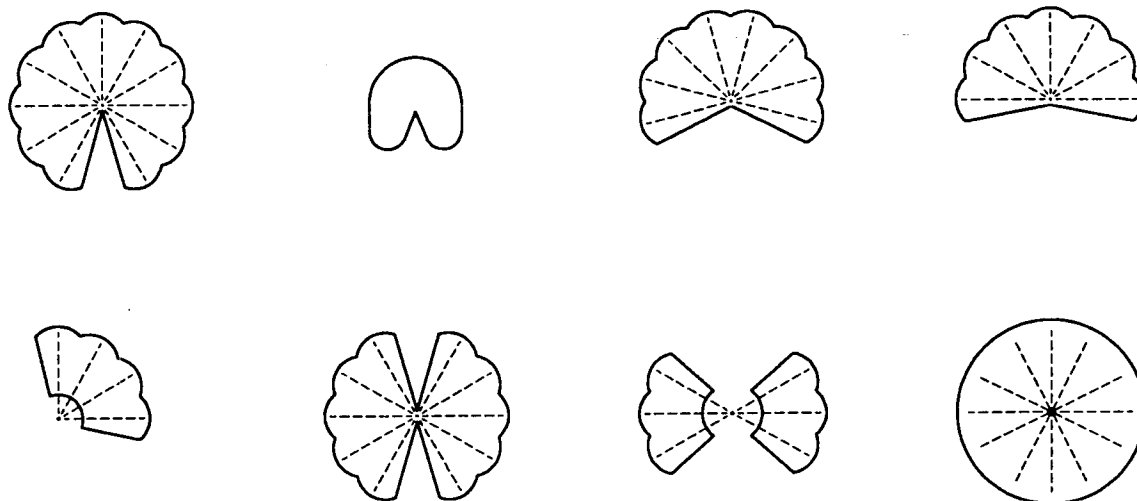|	
Q	= Daily water requirement in gallons.
A	= Area covered by plant canopy in square feet.
E	= PET or Class A pan evaporation in inches per day
WUF	= water use factor (.85) for PET (.7 for pan evaporation)
0.623	= Constant ($7.48 \ gal/ft^3 \div 12"/ft$)

Fig. 6. Typical application patterns of micro-sprinklers and sprinklers.

Table 4. Average potential evapotranspiration (PET) at selected locations (inches per day by month).

Location	Average daily PET by month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alcalde	.08	.09	.14	.20	.28	.32	.26	.23	.17	.15	.09	.06
Artesia	.12	.19	.20	.27	.35	.42	.30	.24	.18	.20	.13	.12
Carlsbad	.14	.19	.20	.28	.37	.44	.30	.26	.20	.22	.15	.10
Clayton	.11	.13	.17	.24	.34	.44	.32	.29	.20	.21	.14	.09
Clovis	.14	.16	.18	.26	.35	.47	.34	.30	.20	.21	.14	.11
Cottonwood	.17	.22	.12	.25	.35	.39	.27	.23	.16	.20	.13	.11
Farmington	.07	.09	.15	.21	.30	.38	.35	.29	.21	.15	.09	.05
Fort Stanton	.08	.12	.16	.20	.24	.34	.24	.23	.13	.14	.12	.11
Los Lunas	.06	.05	.14	.19	.27	.31	.26	.22	.17	.09	.03	.02
Loving	.18	.23	.21	.28	.36	.44	.29	.25	.20	.22	.14	.12
Mesilla Park	.13	.19	.26	.30	.36	.34	.26	.22	.17	.17	.12	.10
Mora	.09	.11	.13	.18	.25	.31	.19	.19	.16	.16	.12	.09
San Miguel	.10	.16	.22	.27	.31	.36	.29	.24	.20	.18	.12	.11
Tucumcari	.14	.15	.19	.27	.33	.44	.39	.29	.18	.14	.09	.07

Location	Accumulated PET by month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alcalde	2.54	2.62	4.49	5.86	8.56	9.45	7.96	7.18	5.17	4.68	2.61	1.90
Artesia	3.68	5.18	6.29	8.10	10.76	12.53	9.30	7.47	5.40	6.15	4.04	3.63
Carlsbad	4.21	5.19	6.25	8.44	11.33	13.19	9.20	7.99	6.00	6.69	4.39	2.96
Clayton	3.51	3.68	5.34	7.33	10.57	13.26	9.96	9.07	6.00	6.30	4.34	2.79
Clovis	4.24	4.45	5.68	7.67	10.72	14.13	10.58	9.39	6.14	6.36	4.26	3.31
Cottonwood	5.42	6.03	3.81	7.59	10.76	11.80	8.47	7.10	4.90	6.08	3.94	3.45
Farmington	2.15	2.64	4.80	6.42	9.25	11.33	10.79	8.89	6.31	4.72	2.56	1.51
Fort Stanton	2.59	3.22	5.02	5.95	7.48	10.33	7.37	7.06	3.87	4.31	3.55	3.56
Los Lunas	1.96	1.38	4.19	5.82	8.29	9.31	8.03	6.94	5.18	2.73	0.96	0.76
Loving	5.57	6.33	6.48	8.27	11.05	13.05	9.05	7.72	5.89	6.69	4.30	3.69
Mesilla Park	4.05	5.21	8.05	8.87	11.10	10.19	8.20	6.75	5.01	5.32	3.45	3.00
Mora	2.94	2.94	4.12	5.29	7.66	9.29	5.99	5.79	4.75	4.99	3.53	2.71
San Miguel	3.02	4.36	6.89	8.17	9.63	10.93	8.90	7.52	5.99	5.64	3.74	3.28
Tucumcari	4.26	4.23	6.03	7.99	10.26	13.25	12.22	9.12	5.54	4.27	2.80	2.06

For trees, the area (A) in equation 1 is the area of a circle with a diameter equal to the diameter of the tree canopy, calculated by:

Equation 2

$$A = \frac{\pi D^2}{4}$$

Substituting this value for A in equation 1 and combining constant numerical values produces the following equation:

Equation 3

$$Q = D^2 \times E \times WUF \times 0.49$$

Where:

Q = Daily water requirement in gallons per tree.

D = Diameter of area within tree canopy in feet.

E = Potential evapotranspiration, inches per day (table 4).

WUF = water use factor (.85 for PET)

Equation 3 can be used to calculate the daily water requirement of trees or other single plants with *circular* canopies.

Table 5 shows the number of gallons of water required to supply 0.85 of daily PET for trees with canopy diameters of 5–70 ft. For a WUF of 0.85, use

Table 5. Gallons of water required per tree per day to supply 0.85 potential evapotranspiration (PET).

Avg. daily PET (in.)	Diameter of drip line of tree													
	5'	10'	15'	20'	25'	30'	35'	40'	45'	50'	55'	60'	65'	70'
	(Gallons of water per tree per day)													
.10	1.04	4.17	9.37	16.66	26.03	37.49	51.02	66.64	84.34	104.13	125.99	149.94	175.97	204.09
.12	1.25	5.00	11.25	19.99	31.24	44.98	61.23	79.97	101.21	124.95	151.19	179.93	211.17	244.90
.14	1.46	5.83	13.12	23.32	36.44	52.48	71.43	93.30	118.08	145.78	176.39	209.92	246.36	285.72
.16	1.67	6.66	14.99	26.66	41.65	59.98	81.63	106.62	134.95	166.60	201.59	239.90	281.55	326.54
.18	1.87	7.50	16.87	29.99	46.86	67.47	91.84	119.95	151.81	187.43	226.78	269.89	316.75	367.35
.20	2.08	8.33	18.84	33.32	52.06	74.97	102.04	133.28	168.68	208.25	251.98	299.88	351.94	408.17
.22	2.29	9.16	20.62	36.65	57.27	82.47	112.25	146.61	185.55	229.08	277.18	329.87	387.14	448.99
.24	2.50	10.00	22.49	39.98	62.48	89.96	122.45	159.94	202.42	249.90	302.38	359.86	422.33	489.80
.26	2.71	10.83	24.37	43.32	67.68	97.46	132.66	173.26	219.29	270.73	327.58	389.84	457.53	530.62
.28	2.92	11.66	26.24	46.65	72.89	104.96	142.86	186.59	236.16	291.55	352.78	419.83	492.72	571.44
.30	3.12	12.50	28.11	49.98	78.09	112.46	153.06	199.92	253.02	312.38	377.97	449.82	527.91	612.26
.32	3.33	13.33	29.99	53.31	83.30	119.95	163.27	213.25	269.89	333.20	403.17	479.81	563.11	653.07
.34	3.54	14.16	31.86	56.64	88.51	127.45	173.47	226.58	286.76	354.03	428.37	509.80	598.30	693.89
.36	3.75	14.99	33.74	59.98	93.71	134.95	183.68	239.90	303.63	374.85	453.57	539.78	633.50	734.71
.38	3.96	15.83	35.61	63.31	98.92	142.44	193.88	253.23	320.50	395.68	478.77	569.77	668.69	775.52
.40	4.17	16.66	37.49	66.64	104.13	149.94	204.09	266.56	337.37	416.50	503.97	599.76	703.89	816.34
.42	4.37	17.49	39.36	69.97	109.33	157.44	214.29	279.89	354.23	437.33	529.16	629.75	739.08	857.16
.44	4.58	18.33	41.23	73.30	114.54	164.93	224.49	293.22	371.10	458.15	554.36	659.74	774.27	897.97
.46	4.79	19.16	43.11	76.64	119.74	172.43	234.70	306.54	387.97	478.98	579.56	689.72	809.47	938.79
.48	5.00	19.99	44.98	79.97	124.95	179.93	244.90	319.87	404.84	499.80	604.76	719.71	844.66	979.61
.50	5.21	20.83	46.86	83.30	130.16	187.43	255.11	333.20	421.71	520.63	629.96	749.70	879.86	1020.43
.52	5.41	21.66	48.73	86.63	135.36	194.92	265.31	346.53	438.57	541.45	655.15	779.69	915.05	1061.24
.54	5.62	22.49	50.60	89.96	140.57	202.42	275.51	359.86	455.44	562.28	680.35	809.68	950.24	1102.06

tables 4 and 5 directly to determine the daily water requirements in gallons. For example, the maximum average daily PET in Mesilla Park (Las Cruces) is 0.36" and occurs in the month of May.

Table 5 shows that 183.6 gallons of water per day will be required to supply 0.85 of potential evapotranspiration for a tree with a canopy 35 ft in diameter. Note: no allowance has been made for rainfall. Allowing for normal or expected rainfall, often will temporarily reduce the total amount of water that must be supplied by the irrigation system to meet peak water usage. If allowances are made for rainfall, the system will have insufficient capacity to maintain potential yields and prevent tree damage and loss in the event of extended drought.

Water Requirements of Pecan Trees

Researchers in the Southeast and Southwest have reported widely differing estimates of the water requirements of pecan trees. Experience in New Mexico has indicated that a mature pecan tree will use 160–240 gal per day during the peak water-use period.

For short periods during the nut-filling stage, water use may increase to almost 100% of pan evaporation or to 1.21 PET. With systems designed at 0.85 PET, enough water usually can be stored in the root zone in advance to supply the requirements of pecan trees during this maximum use period with proper soil moisture management. Pecan orchard water consumption can be correlated to the number of trees per acre and respective tree trunk diameter.

Capacity of Irrigation Water Source

Drip irrigation systems should be planned to deliver the eventual maximum daily water requirement in 1 day or 24 hours. The required water supply is calculated by the number of emitters and the discharge rate of each emitter. Water needs for young orchards are low, and one or two emitters will deliver sufficient water for each small tree. Emitters must be added as trees grow and require more water. Each additional emitter increases the amount of water that the irrigation well or other water source must supply.

The rate (in GPM) that an irrigation well or other water supply source must deliver for each acre irrigated can be calculated as follows:

Equation 4

$$GPM/acre = \frac{Number\ of\ trees\ per\ acre\ x\ GPH\ per\ tree}{60\ minutes\ per\ hour}$$

In table 6, the required water delivery rates calculated with equation 4 are listed for various hourly water application rates and tree spacings. Three to six gallons of water daily will usually supply the water requirement of a tree during the first and second years after planting. Thus, the irrigation system needs to be operated for only 3–6 hr/day or an equivalent amount of time per week during maximum water use months when one 1-GPH emitter is used for each tree. However, as trees grow, additional water must be available to supply daily requirements.

Table 6. Required pumping rate in gallons per minute per acre.

	$GPM/acre = \dfrac{Number\ of\ trees\ per\ acre\ x\ GPH\ per\ tree}{60\ minutes\ per\ hour}$										
	Gallons per hour (GPH) per tree										
Trees per acre	0.50	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
27[a]	0.23	0.45	0.90	1.35	1.80	2.25	2.70	3.15	3.60	4.05	6.67
36[b]	0.30	0.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80	5.40	
48[c]	0.40	0.80	1.60	2.40	3.20	4.00	4.80	5.60	6.40		
70[d]	0.59	1.17	2.34	3.51	4.68	5.85	7.00	8.17			
87[e]	0.73	1.45	2.90	4.36	5.81	7.26	8.70				
109[f]	0.91	1.82	3.63	5.45	7.27	9.08					
116[g]	0.97	1.94	3.87	5.81	7.74						
145[h]	1.21	2.42	4.80	7.25							

[a] 40' x 40' spacing [b] 35' x 35' spacing [e] 20' x 25' spacing [d] 25' x 25' spacing
[c] 30' x 30' spacing [f] 20' x 20' spacing [g] 15' x 25' spacing [h] 15' x 20' spacing

Examples

1. Trees are spaced 30 ft x 30 ft in a 100-acre orchard. The water requirement for mature trees is anticipated to be 8 GPH per tree. How much water should the irrigation well deliver? *640 GPM* (6.4 GPM/acre x 100 acres = 640 GPM).

2. With the same tree spacing and acreage (30 ft x 30 ft and 100 acres), what pumping rate is required to apply 1 GPH per tree during the first year after transplanting? *80 GPM* (.80 GPM/acre x 100 acres = 80).

3. How many acres of trees spaced 35 ft x 35 ft will a 50-GPM well irrigate when the peak water requirement is estimated to be 8 GPH per tree? *10.4 acres* (50 GPM ÷ 4.8 GPM/acre = 10.4 acres).

FERTILIZER INJECTION

Dry fertilizer broadcast on the soil surface may not be moved into the root zone effectively because only a small area of soil is wet by drip emitters. However, fertilizer can be applied effectively through the irrigation system and this method is recommended. Excellent injection equipment is available that usually can be connected into the main pipeline so fertilizer can be routed selectively to all trees in the orchard. To prevent emitter plugging, fertilizer must be injected upstream from the filter so undissolved fertilizer material and precipitates will be contained by the filter. Select an injector that operates properly on the electrical voltage, water pressure, and water flow rate available in the orchard. The injector should also have adequate capacity to apply the fertilizer needs of *mature* trees, as this equipment normally has a long lifetime.

Highly soluble nitrogen fertilizers such as potassium nitrate, calcium nitrate, ammonium nitrate, ammonium polyphosphate, and liquid uran and urea nitrogen can be applied by the drip irrigation system.

Dissolve or mix the dry fertilizer material in water to make the proper concentrate, making certain that all fertilizer is in solution. Liquid nitrogen such as uran and urea normally can be applied undiluted by the irrigation system. Mix appropriate amounts of the fertilizer solution and irrigation water prior to injection to check for precipitate formation that can clog the emitters and filter. A precipitate is frequently formed when anhydrous ammonia is added to irrigation water; other nitrogen fertilizers may also produce precipitates at high concentrations, especially with lower-quality water.

Begin fertilizer injection when the irrigation system is applying water at the normal rate. Check the application rate by timing injection of a specific quantity of material. Complete injection before the irrigation cycle ends in order to move fertilizer out of the irrigation system and into the root zone. One to three hours may be required to move fertilizer material to trees at the ends of lateral pipelines, especially when only one emitter is used for each tree.

SALINITY MANAGEMENT

All water from streams and underground sources contains dissolved materials known chemically as salts. In many areas of New Mexico, irrigation water may contain enough salt to be injurious to plants, as applying irrigation water adds salt to the soil, where it will accumulate unless it is moved below the root zone by rainfall or excess irrigation water. When the amount of salt added exceeds the amount removed by leaching, salts may accumulate until the concentration in the soil solution becomes harmful to plants. High soil salinity interferes with the plants' ability to take up water. In addition, certain salts or ions can produce specific toxic effects. Water containing high sodium levels requires special management because sodium affects soil structure and chemistry.

Irrigation water is considered poor quality when it contains moderate to large amounts of salt. Poor-quality water often can be used more successfully with drip irrigation than with sprinkler or surface irrigation, as less total salt is added with drip irrigation because less water is applied. In addition, a uniformly high soil moisture level is maintained with drip irrigation, which makes more water available to trees and moves or leaches the salts below the root zone.

Even with good irrigation water management, salt will accumulate at the edges of the wet pattern (fig. 5), and some artificial leaching (removal of salts with drainage) may be required. Rainfall is not adequate in most areas of the state to accomplish any required leaching of salts, and the extra irrigation water is required in these areas. In most cases, operating the irrigation system when the water requirement of the trees is low can accomplish the required leaching. When irrigation water contains significant quantities of salt, an annual salinity analysis of soil samples from the root zone is advisable. Do not guess about water and soil salinity: Know your water quality by having it laboratory tested and manage it to prevent problems, ensuring the long-term productivity of the orchard.

OPERATING DRIP IRRIGATION SYSTEMS

With drip systems, continuous irrigation from early spring through the summer is not required. Orchard water requirements are influenced by tree size and growth stage as well as temperature, relative humidity, and wind velocity. An ideal system applies just enough water to replace the amount used by trees the previous day: uniform soil moisture content is maintained, and the volume of moistened soil neither increases nor decreases.

Estimate the daily operating time in hours by dividing the daily water requirement (table 5) by the water application rate at each tree in GPH:

Equation 5

$$\text{Daily operating time (hr)} = \frac{\text{Daily water requirement of each tree (gal)}}{\text{Water application rate to each tree (GPH)}}$$

The irrigation system is operated for shorter time periods early in the season; operating time increases as evaporation rates and tree use increase (table 5). When the operation time calculated with equation 5 exceeds 24 hr/day, additional emitters must be added for each tree.

In new plantings, one emitter often is used to supply the small quantity of water needed by each tree. As the trees grow, their increased water requirement is provided by longer daily operation until additional emitters are required. The drip system will have more capacity than needed during the first 3–4 years, but design capacity will be reached when enough emitters have been added to supply the amount of water needed by mature trees. Continuous operation will likely be required during months of maximum potential evapotranspiration.

Operate the system long enough (24, 48 or 72 hr) early in the season to supply enough water to "fill" the soil root zone. (This is often done when applying fertilizer.) The system then operates only long enough to replenish the amount of water removed by the trees. Also, operate the system 24–48 hr following tree planting to wet and settle soil around tree roots. Applying too much water during the season can hinder tree growth and damage roots by causing poor soil aeration, especially in heavy soils with slow water movement.

Irrigation time can be controlled manually with time clocks or with moisture-sensing instruments that activate pump controls and automatic valves. Operate manually controlled or set time-clock-controlled systems to apply the required amount of water based on potential evapotranspiration (table 4) or estimated water requirement. Inspect the orchard regularly to determine whether the daily irrigation time should be adjusted.

Soil-moisture-sensing instruments such as tensiometers and gypsum blocks can help in making irrigation management decisions. Install instruments to sense soil moisture at two depths, such as 12" and 36". Use two or more sensing locations for each 20 acres of orchard unless tree size varies within smaller areas or soil types change significantly. Locate tensiometers in an unsaturated area within the soil wetting pattern of an emitter. Irrigation for most soils is started when the tensiometer gauge reads between 20 and 40 centibars; however, the exact gauge reading can be determined by trial.

Drip irrigation systems can be completely automated with switching tensiometers that activate sys-

tem controls to start and stop irrigation. Automatic control is convenient and may conserve irrigation water by preventing over-irrigation. However, all orchards, including those with automatic drip irrigation systems, should be inspected regularly and any necessary system maintenance and adjustments performed promptly.

EMITTER CLOGGING CONTROL

Other than proper system design, the greatest potential problem for the operator of a drip irrigation system is emitter clogging. Water passages in emitters are very small and can easily become clogged by minerals or organic matter. Clogging can reduce emission rates and cause non-uniform water distribution, leading to plant stress and limited production.

Contaminants are often present in irrigation water. Contaminants may be soil particles, living or dead organic materials, or scale from rusty pipes. In some cases, contaminants are trapped in the system during installation. These include insects, teflon tape, PVC pipe shavings, organic material, and soil particles. Contaminants can grow, aggregate, or precipitate in water as it stands in the lines or evaporates from emitters or orifices between irrigations. Iron oxide, manganese dioxide, calcium carbonate, algae, and bacterial slimes can form in drip systems under certain circumstances.

The solution to clogging must be based on the particular problem. Emitter clogging can be divided into three groups: physical, biological, and chemical.

Physical clogging is caused by substances such as soil particles (sand and silt), plant material, pipe rust, and debris. Physical clogging is prevented by selecting a filter system matched to the emitter orifice size and type.

Biological clogging is caused by the growth of algae, bacteria, or slime, usually in the drip tubing (lateral lines). Selecting emitters with large orifices and using black pipe may reduce clogging. In many cases chlorination is necessary. To treat biological clogging initially, the system can be flushed with a chlorine concentration of 10 ppm for an hour. If necessary, concentrations are then increased gradually to about 50 ppm. If the water pH is high, acid may be injected to lower pH to 7 or below to reduce the concentration of chlorine needed. Some irrigators recommend routine injection of 1–2 ppm chlorine to control algae growth. To calculate fluid ounces of chlorine needed per 1000 gallons of water, use the following equation:

Equation 6

$$\text{Ounces chlorine required per 1000 gallons water} = \frac{\text{ppm chlorine x 13.3}}{\text{\% chlorine of source}}$$

Where:

a) chlorine in bleach is 5.25% or 10% (check label), and

b) chlorine content of calcium by hypochlorite is 35% or 70%.

Chemical clogging is caused by the precipitation of calcium, magnesium, iron, or fertilizer from the irrigation water. Determining the quality of irrigation water by laboratory analysis is helpful in determining the potential for clogging and the most effective treatment. Table 7 lists concentrations of some elements that will lead to clogging problems. Sulfuric and hypochloric acids can be injected to lower water pH and reduce the amount of chemical precipitates. Regular acid treatments are usually necessary to clean emitter passages when concentrations of calcium or magnesium exceed 50 ppm or when water pH is greater than 8.0. Experimentation is the best method to determine the concentration of acid needed. First, add acid to lower the pH to about 6.5. Expose emitters to this concentration for 30 min to 1 hr. Add more acid as necessary until the pH is lowered to about 2.

Table 7. Recommended chemical treatments for selected conditions.

Water quality	Suggested treatment
Ca>50 ppm Mg>50 ppm	Hard water, caused by high concentrations of calcium (Ca) or magnesium (Mg), can reduce flow rates by the buildup of scale on pipe walls and emitters. Periodic injection of hydrochloric acid (HCl) solution may be required throughout the season. Lower concentrations of Ca and Mg may require HCl treatment every 2–4 yr.
Fe>0.5 ppm S>0.5 ppm	Iron (Fe), sulphur (S), and other metal contaminants create an environment in water that is conducive to bacterial activity. Byproducts of bacteria in combination with the fine (<100 micron) suspended solids can cause system plugging. Bacterial activity can be controlled by chlorine injection and line flushing on a regular basis throughout the irrigation season. Bacterial activity is prevalent in concentrations of Fe and S over 0.5 ppm, but also occurs at lower concentrations.

Source: British Columbia Ministry of Agriculture, "Water Treatment Guidelines for Trickle Irrigation," Engineering Reference Informatio R512.000, 1982.

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Reprinted January 2002   **Las Cruces, NM**
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